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(4/1/93 - 6/30/93)

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RF VACUUM MICROELECTRONICS

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1.0 Emitter Fabrication

1.1 Mask Design and Procurement

Both masks have been procured and used to fabricate devices. There was no design and procurement activity during this period.

1.2 Process Optimization Experiments

1.2.2 Process #1.2

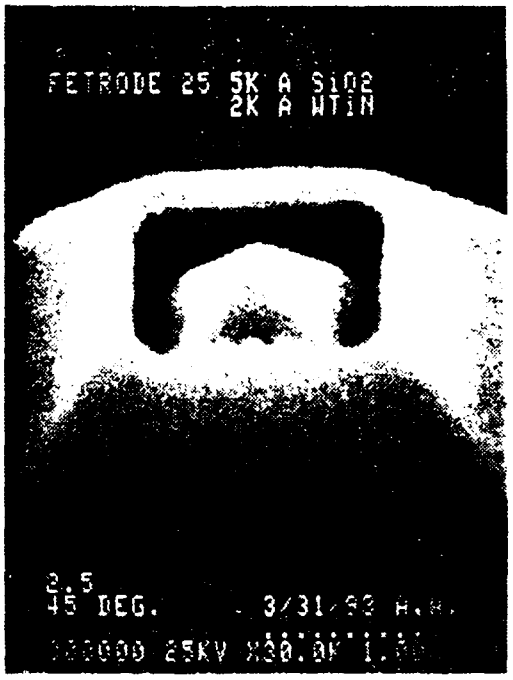
Processing of lot 1.2 was completed in this quarter. One lot of four wafers was processed, two of the wafers in the lot were of sufficient quality to test in vacuum. Test results were mixed, devices operated to higher breakdown potentials but emission current levels were not greatly increased. A number of in-situ gas and plasma exposure measurements were performed. A complete description of the test results is given in section 2.3.

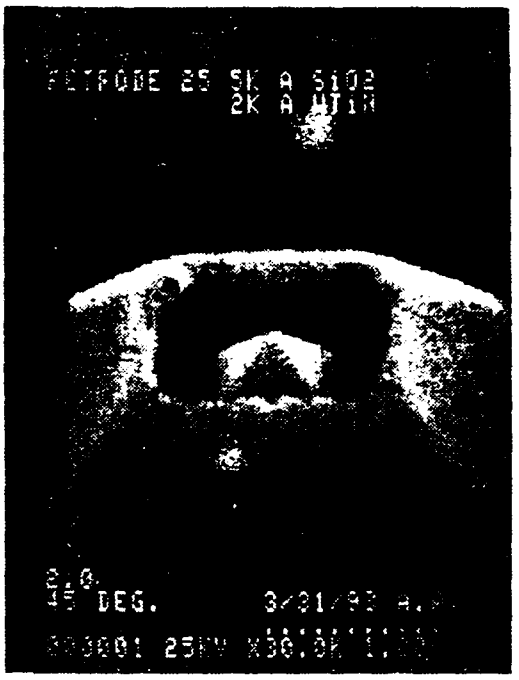
1.2.3 Process #2.1

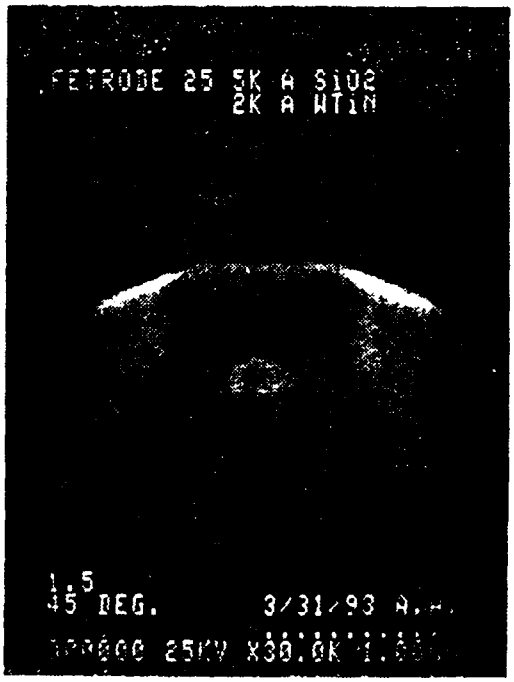
The first two wafers of a 4 wafer matrix were completed in this quarter. This experiment was basically designed to test and verify some of the early conclusions. The variables under consideration were: the dielectric thickness at two levels (5000 Å and 10,000 Å), the thickness of the gate metal (at two levels), and the aperture size of the emitters (also at two levels). Previous levels of these variables were too close together to detect definitive correlation to emission. The dielectric levels were chosen based on the observation that 4000Å and 6000Å did not produce significant differences while the 10,000Å of lot 1.2 did give greater breakdown, but we had no control sample with thinner dielectric in that process run and other things were also changed. Aperture size seemed not to have an effect significant relative to variation in the first run so we decided to increase the apertures to very large dimensions. From theory we know that this must have an effect on field enhancement and thus emission and can be used to calibrate the tip radius. Variables which were not considered based on experiment 1.1 were: tip material and dielectric type. Representative photos of the devices on two completed wafers are shown in an attached figure. The wafers are designated FETRODE 25 and FETRODE 26 (serial numbering from program inception). FETRODE 25 has a thinned oxide and therefore the emitter tips are higher relative to the gate metal. The 2.5μm emitters on this wafer, in fact, protrude through the gate metal slightly. FETRODE 26, with 10,000Å oxide has only slightly larger apertures but the location of the tip relative to the gate is quite different; for all tip sizes the tips are below the gate aperture and for the smaller sizes, 1.5μm and 1.0μm the tip is not visible in the 45° angle SEM photos attached.

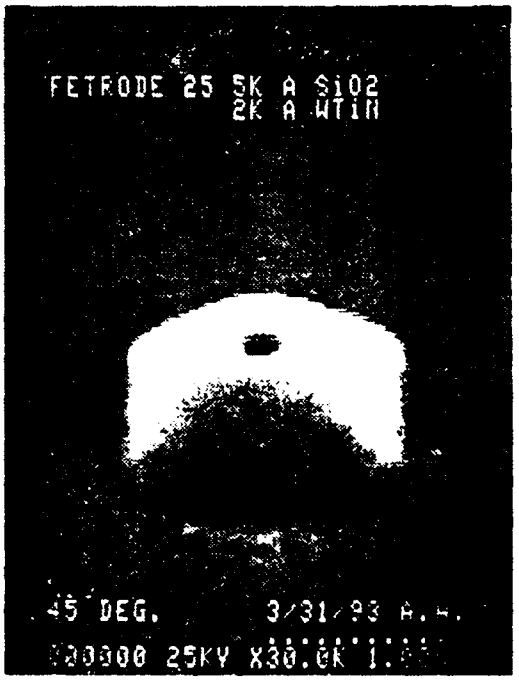
In-situ treatment is the primary effect under study currently and we wanted to simplify the variation in process conditions as much as possible.

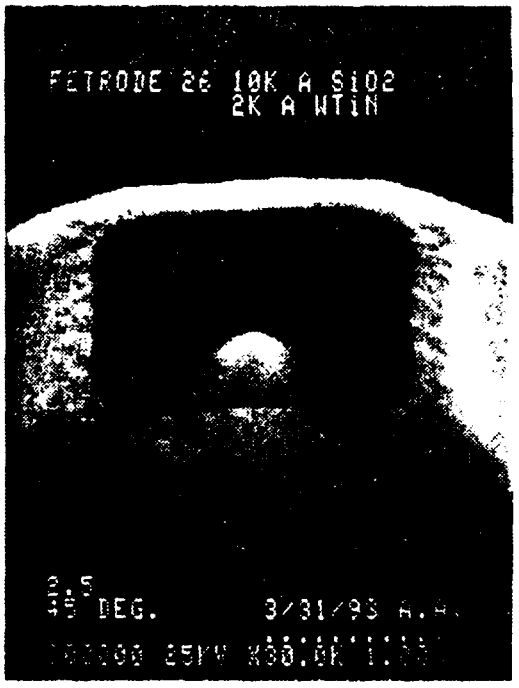
The best emission results to date were obtained on sample 26 (10,000Å dielectric). We obtained 80μA of emission and observed Fowler-Nordheim behavior over seven orders of magnitude in current.







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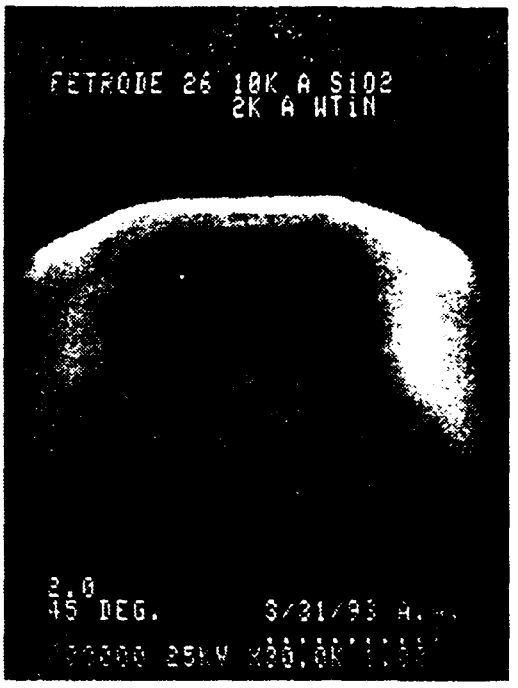
2K A WTiN
2.5
45 DEG.
3/31/93 H.H.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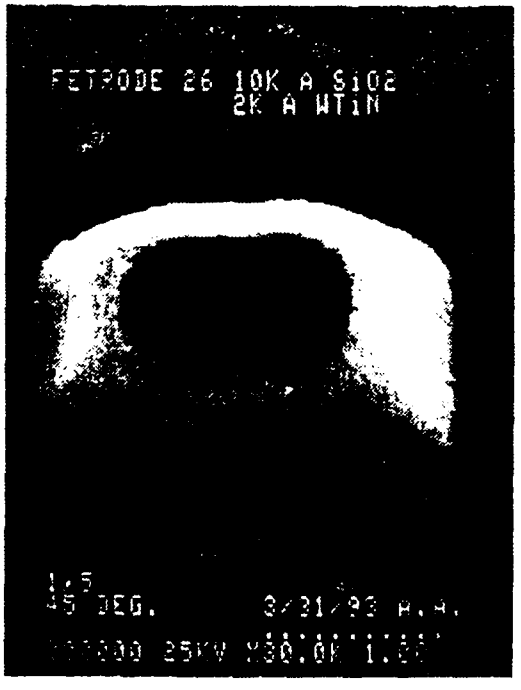
2K A WTiN
2.0
45 DEG.
3/31/93 H.H.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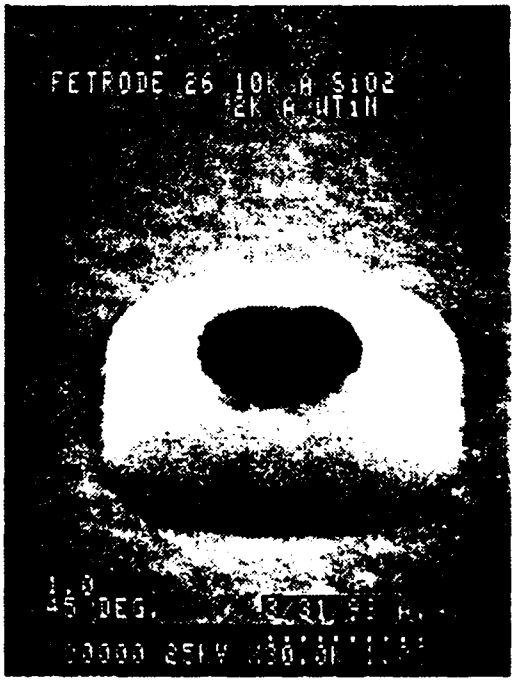
2K A WTiN
1.5
45 DEG.
3/31/93 H.H.


FETRODE 26 10K A SiO2
2K A WTiN
1.0
45 DEG.

2.0 Emission Testing

In this test period we tested 37 devices with 13 different geometrical configurations and 3 different build parameters. Table I is a summary listing of all the devices tested. Various devices were processed with plasmas of O_2 and H_2 at different times when the devices warranted extended testing. The best device (F26-7 E3) tested in this period achieved 82 micro Amperes of emission current before the device failed. Fig.1. shows this data.

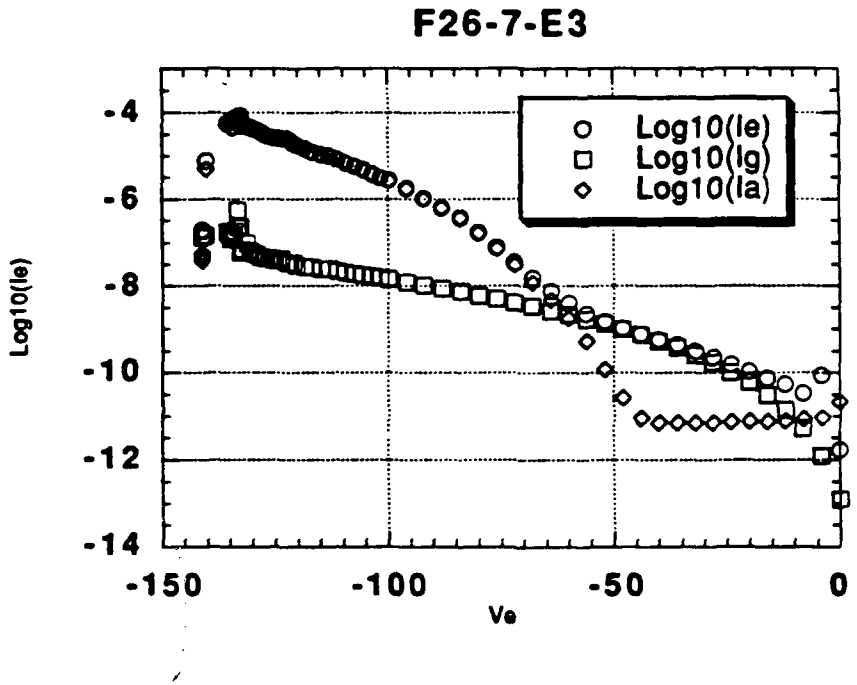


Figure 1 Best performing device in this test period.

All of the devices tested in this period had molybdenum tip. Devices F25 have 0.5 micrometer thick dielectric's and F26 have 1.0 micrometer dielectric's. In general the thicker dielectric's correlate with higher emission currents.

On various devices (see table 1) we tried various plasma processes using O_2 and H_2. The results in general were the same as reported in the last report. We observed no new effects.

SAMLPE ID		RUN#	DESCRIPTION OF RUN
F19-18	C3	1	0.1 uA leakage at -55 v. No emission.
		2	Device blown: 15 uA @ -3 v.
F19-18	B3	1	0.1 uA leakage at -44 v. No emission.
		2	Device blown: 15 uA @ -3v.
F19-18	D3	1	0.1 uA leakage at -60 v. No emission.
		2	Got maybe 30 nA at - 81v with 2 uA leakage
		3	Got maybe 2 nA at -108v with 7 uA leakage
		4	Did H2 bleed. Got maybe .6 nA @ -100v
		5	Blew device at -108v. Was holding with 5 uA leakage.
F19-19	C3	1	Shorted from start.
F19-19	B3	1	Tested to -42 v. Start of emission -41 v. Ia 15nA.
		2	Tested to -44 v, Ia = 12 nA.
		3	Device OK to -5 volts
F19-19	D3	1	0.1 uA leakage at -54 v. No emission.
F19-20	A2	1	0.1 uA leakage at -17 v. No emission.
F19-20	B2	1	Tested to -100 v. Disconnected device.
F19-20	C2	1	0.1 uA leakage at -51 v. No emission.
		2	Got 8uA emission with 0.9 uA leakage at -69v after H2 treatment. Save for further testing
F19-21	A2	1	0.1 uA leakage at -19 v. No emission.
F19-21	B2	1	Tested to -155 v. Disconnected device.
F19-21	C2	1	0.1 uA leakage at -20 v. No emission.
		2	0.5 uA leakage at -70 v after H2 treatment. No emission.
		3	Probably croaked it at -89 volts. Must re-check
F19-22	A2	1	Shorted from start.
F19-22	B2	1	Spurious shut off at -27 v.
		2	Tested to -166 v. Disconnected device.
F19-22	C2	1	0.1 uA leakage at -53 v. No emission.
		2	0.1 uA leakage at -22 v. No emission.
F19-23	A2	1	0.1 uA leakage at -36 v. No emission.
F19-23	B2	1	Tested to -100 v. Disconnected device.
F19-23	C2	1	0.1 uA leakage at -41 v. No emission.
F25-1	F3	1	Emission first noted at -60 v. Was 1.3 uA with 33 nA leakage at -114 v. Held for 30 min. Leakage rose to 0.3 uA, then started falling when program hung.
		2	Came right back to 3 uA emission, 60 nA leakage at -114 v. Program hung again while holding.
		3	Came right back at -114 v. Went to - 132 v, got 5 uA emission and .16 uA leakage. Then hung while holding.
		4	Did a whole bunch of stuff including H2 and Ar gas bleeding. Blew device at end.
		5	Was very leaky. Bled in O2 gas. Eventually really blew device.
F25-1	F3	1	Emission started at -42V. Emission of .4uA at -73V, leakage .9uA. Held for 1Hr Emission

			rose to 3.2uA leakage to 1.3uA. Til blew.
		2	Emission 0.1uA, leakage 1uA at -122V.
F25-1	F3	1	Emission started at -60 volts. At -80 volts, emission of 13 nA, leakage 81 nA. Leakage increased rapidly. At -94 v, leakage 1.1 uA, emission down to 7 nA.
		2	Emission started at -68 volts. At -96 v, emission was 9 nA, leakage 1.3 uA. At -116 v, emission was 0.8 uA, leakage 4.4 uA, then device blew.
F25-1	F3	1	Emission noted at -64 V. Run stopped at -92 V with emission at 12 nA, leakage at 2.1 uA
		2	Treated with A at 1 E-5 Torr while holding at -90 V. After treatment leakage was 0.5 uA emission 0.1 uA.
		3	I-V curve. At -90 v, emission was 0.11 uA, leakage 0.54 uA
		4	While trying to get to 1 E-4 Torr, gate current tripped. At -92 v, emission was 0.1 ua, leakage 0.5 uA.
		5	On way up, at -92 v, emission was 0.2 uA, leakage was1.6 uA. While trying to get to 1 E-3 Torr, apparently arced and failed short while holding at -96 v.
		6	Not blown, emission 2.3 uA @ -98 V, leakage\ 4.3 uA. Apparently then blew like above. May or may not be blown.
F26-5	E1	1	At -267 v, got 0.7 uA emission, .09 uA leakage Then started anode sweeps. 2-9 Anode sweeps from Vge = -150 v to -290 v. Failed during last sweep
F26-5	E1	1	Very leaky. At -20 v, leakage was 56 uA. No discernable emission.
F26-5	E1	1	Only had time to get to -68 v: No leakage or emission.
		2	Emission first noticed at -96v. At -192v emission was .19 uA, leakage 0.4 nA. Sudden event at -200v, leakage shot up to 1 uA. Started holding at -204 v with emission at .3uA, leakage at 1.2 uA. Device failed after 5 min.
		3	At -104 v, leakage 45 uA, emission 5.4 nA
F25-2	F3	1	Emission 1st noted at -100 V. At -130 V, emission was 0.6 nA, leakage 0.5 uA. Apparently failed at -133 V
		2	Blown.
F25-2	F3	1	Emission 1st noted at -44 V. Emission was 6 nA at -64 V, leakage 13 nA. Blew at -72 V.
		2	Blown.
F25-7	E3	1	Saw trace emission at -104 v. Device failed at -120 v
F25-7	E3	1	At -2v, had 1.7 uA leakage.
		2	At -2v, had 1.7 uA leakage, 30 uA at - 6 volts.
F26-1	F3	1	No emission noted at -288 V. Leakage 7 pA
		2	No emission noted at -392 V. Leakage 4 pA
F26-1	F3	1	trace emission 1nA at -200V.
		2	3 nA emission and 18 nA leakage @ -300 v
		3	80 nA emission & 10 uA leakage @ -312 v.
F26-1	F3	1	Emission 1st noted at -160 V. At -176 V, emission 2.3 nA, leakage 0.25 uA. Last stable point at -192 V: Emission .27 uA, leakage

			1.4 uA. Device blew at -208 V.
		2	Blown
F26-7	E3	1	Emission first seen at -170 v. Got 0.5 uA at -250 v with 0.2 uA leakage. At -274 v got .2 uA emission with .55 uA leakage.
F26-7	E3	1	Got 11 uA emission and 26 uA leakage @ -287 v
		2	Restarted at -100 v: 1 uA leakage, 2 nA emission. at -196v, had 52 uA leakage, 0.6 uA emission. Bled in O2 gas at 2e-7 Torr; over 6 minutes, leakage fell to 13 uA, emission 5 nA.
		3	Restarted at -100 v: .3 uA leakage, no emission. At -204v, had 7 uA leakage, 10 nA emission. At -260 v, 66 uA leakage, .3 uA emission. While holding, leakage went to 103 uA, emission 1 uA.
F26-7	E3	1	Initially got 1 uA emission with 18 nA leakage at -102 v. While holding, fell to .6 uA emission with 17 nA leakage after 20 minutes.
		2	At -119 v, had 8 uA emission with 30 nA leakage. First saw emission at -
		3	11 Anode sweeps
		4	Got 82 uA emission with .2 uA leakage at -133 v before tip blew. Then was at 40 nA emission with 140 nA leakage at -141 v.
F26-2	F3	1	Emission 1st noted at -160 v. At -184, emission 12 nA, leakage 37 nA. At -200 V,\ emission 59 nA, leakage 2 nA.
		2	Emission 1st noted at -168 V. At -184 V, emission 4.5 nA, leakage 1.9 nA. Started holding at -240 V, emission 0.11 uA, leakage 0.49 uA. Device failed after two additional measurements.
		3	Blown
F26-2	F3	1	Emission 1st noted at -176 V. At -192 V emission was 5 nA, leakage 4 nA. Last stable point was -216 V, emission 73 nA, leakage 151 nA. Device blew at -220 V.
		2	Blown

========== END ==========